

## 氣體放電電鍵： (二) 爲控制 10 厘米波帶的低權級微波訊號用

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在上文中, 筆者曾敘述改製雷達用的 1B24 式 *TR* 管, 作爲控制 3 厘米波帶的低權級微波訊號之用。所根據的原理是利用保活電子 (keep-alive electrons) 與微波電場所起的相互作用而使訊號發生衰減。實驗的結果指出, 欲得極大的衰減必須滿足下列條件: (一) 由保活放電所供給的電子的密度必須甚大; (二) 管中兩主要電極間的微波電場必須高度地集中, 俾能與電子發生較大的相互作用; (三) 管中所裝氣體對於電子的附着係數必須甚低, 而電離係數則必須甚高。本文所敘述的, 是根據此原理而改製雷達用的 1B27 式 *TR* 管, 以控制 10 厘米波帶的微波訊號的強度。1B27 式 *TR* 管的構造與上文中所用的 1B24 式不同, 因而改製的方式也不相同。在此式 *TR* 管中, 除去須將保活電極的深度減小以外, 還須令電極的頂端向中空電極的內壁傾斜, 且管中所裝的氣體用氮氣或氫均可。若保活電極的深度爲零, 而其頂端與中空電極的內壁的間隔爲 0.7 毫米, 所裝的氣體爲 4 毫米水銀柱高的氮氣時, 則當保活電流爲 1 毫安培時所得的衰減爲 30 分貝耳 (*db*)。在此時所加的保活電壓爲 450 伏特。此種改製管的壽命極長, 在連續使用數百小時後其特性並無顯著的變化。

## A GAS DISCHARGE SWITCH: II. FOR CONTROLLING LOW LEVEL 10 CM-BAND MICROWAVE SIGNALS\*

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### ABSTRACT

Based on the interaction between r-f field and the electrons furnished from an auxiliary d-c discharge, a gas discharge switch has been developed for controlling low-level 10 cm-band signals by modifying the keep-alive electrode of a cell type 1B27 TR tube. It has been found that the attenuation was considerably increased when the top of the keep-alive electrode was off-center and close to the side of the lower hollow cylindrical post. Nitrogen or argon at a pressure of about 4 mm Hg was found to be appropriate as a gas filling for such a switch. An attenuation of more than 30 db was obtained from a tube having a keep-alive depth of 0.0 mm and a distance of 0.7 mm from the keep-alive to lower-hollow-cone. The gas filling was nitrogen at 4 mm Hg, and the keep-alive current was 1 ma with a d-c gap voltage of about 450 volts. Such a switch has a very long life, as there was no appreciable change in the tube behavior after operating continuously for several hundred hours.

In the preceding paper,<sup>1</sup> an electronic switch for controlling low power 3 cm-band signals by modifying an integral cavity type 1B24 TR tube has been described. The underlying principle of such a switch is the interaction between the r-f field and the electrons furnished from an auxiliary d-c discharge, the so-called keep-alive discharge. It has been found that in order to obtain a high attenuation when the keep-alive current is turned on, the following conditions must be fulfilled: (1) The number of electrons per unit volume furnished from the keep-alive discharge must be large; (2) the r-f field must be highly concentrated at a certain region so that the interaction with the electrons will be large; (3) the gas filling used in the tube must, among other things, have a low electron attachment coefficient and a high differential ionization constant for electrons. In the present paper,

\*This work was completed in October, 1945 while the author was associated with the Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Mass., U.S.A. A preliminary report on this work was written by the author in 1945 (Radiation Laboratory Report 979).

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1. T. S. Kê, *Chinese J. Phys.* **8** (1951), 16.

a similar switch, based on the same principle, is to be developed for controlling low power 10 cm-band signals by modifying a 1B27 TR tube. This tube is a cell type TR tube intended to operate in the wave length range from 7.8 cm to 14 cm, when used with the appropriate cavities.<sup>2</sup> It is tuned by varying the gap spacing, thus varying the capacitance of the resonance circuit. An X-ray radiograph of such a tube is shown in Fig. 1. It has the advantage over the integral cavity type tube in that the tube body consists essentially of a glass envelope into which two thin copper discs were sealed to support the upper and lower truncated conical posts. It may thus be baked out easily to remove the gases adsorbed.

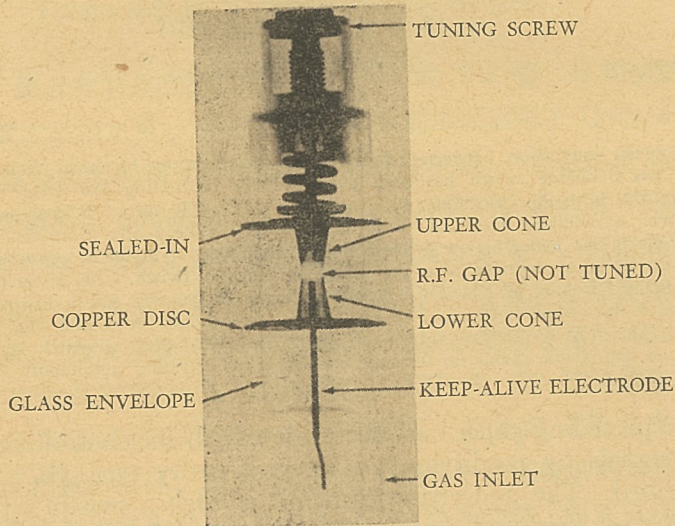


Fig. 1. X-ray radiograph of an 1B27 TR tube.

### *Keep-alive Electrode*

The keep-alive depth (vertical distance from the keep-alive electrode to the top of the lower cone) of an ordinary 1B27 TR tube is about 4.5 mm which is great enough to prevent excessive keep-alive interaction. In order to obtain a high attenuation when the keep-alive (at a negative potential) is on, it is obvious that the keep-alive depth must be decreased. Several standard 1B27s were thus modified so that the keep-alive electrode, which is situated inside the lower hollow cone, was pulled up to be nearer to the gap formed between the upper and lower truncated cones. The attenuation measurement was made by an arrangement shown in Fig. 2. The line was tuned to a wave-length of 10.4 cm.

2. For a description, see Smullin and Montgomery, *Microwave Duplexers* (McGraw-Hill Book Co., 1948), Chap. II.

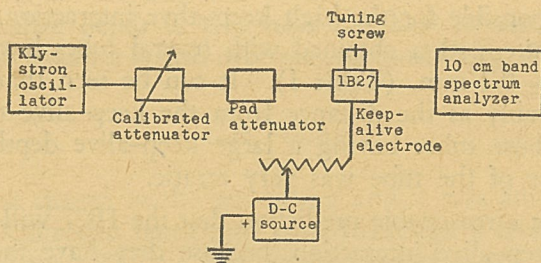


Fig. 2. Block diagram of the equipment used in making attenuation measurements.

It has been found that with the keep-alive electrode situated at the center of the lower hollow cone (having a top aperture of about 4 mm), there was no appreciable change in attenuation when the keep-alive current was turned off and on, even when the keep-alive electrode was pulled all the way up to the top of the lower cone. Since the diameter of the keep-alive electrode is about 1 mm, the distance from the keep-alive to the edge of the cone, when the keep-alive depth is zero, is about 1.5 mm which is probably still too large to produce a high attenuation.

During the early stage of the development of 721A TR tube, which is similar in general structure with 1B27 TR tube but is non-tunable, Smullin<sup>3</sup> observed casually that the keep-alive interaction loss was sometimes as high as 20 db with a gas filling of 15 mm Hg of hydrogen and 15 mm Hg of water vapor. A careful examination of the X-ray radiographs of a number of the old 721A tubes revealed that the off-centering of the keep-alive electrode

TABLE I.

Tube No.	Keep-alive depth (mm)	Keep-alive to cone edge (mm)	Gap-distance in tuned position (mm)	Attenuation (db)
279L	-0.1+	0.2	0.8	20
281L	+0.1+	0.3+	0.7	15
278L	-0.2	0.4+	0.7	9-16.6 unstable 2.5
277L	-0.1+	0.5	0.8	
282L	-0.05	0.8	0.75	2
276L	-0.1-	0.8	0.75	1.5

3. L. D. Smullin, private communication to the author.

was probably responsible for the high keep-alive interaction. The following table shows the attenuation obtained with several tubes having a keep-alive depth less than  $\pm 0.2$  mm. (Table I). It can be seen that the attenuation increases considerably as the distance from the keep-alive to the cone edge decreases. For those tubes having a large keep-alive depth, say, above 0.5 mm, the behavior of the tube was very erratic.

It seems to be a reasonable prediction that the 1B27 will behave similarly to 721A as to keep-alive interaction, because they have the same structure except for difference in size. A series of 1B27s were thus modified such that the keep-alive depth was very small and were off-centered to various extents. Two typical ones are shown in Fig. 3. It has been found that the attenuation

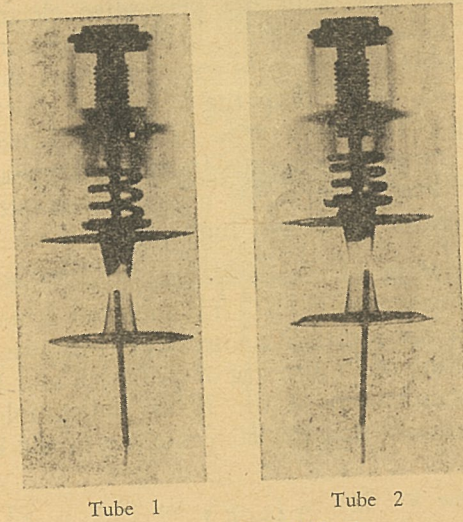


Fig. 3. Typical examples of modified 1B27 tube.  
 Keep-alive depth: Tube 1, 0.0 mm; tube 2, -0.2 mm;  
 the un-modified tube shown in Fig. 1, 1.0 mm.  
 Distance from keep-alive to cone edge:  
 Tube 1, 0.7 mm; tube 2, 0.5 mm; tube in Fig. 1,  
 1.6 mm.

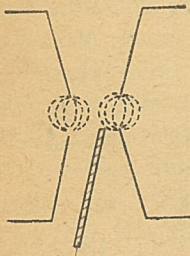


Fig. 4. Illustrating the distribution of r-f field around the edges of the truncated cones.

does increase with the off-centering. This is in agreement with the theory, because the r-f field is more concentrated around the ends of the upper and lower cones, and there the interaction with the electrons will be larger (Fig. 4). The off-centering of the keep-alive electrode brings the electrode closer to the edges of the cones and therefore the electrons will have more chance of being drawn into the region where the r-f field is most concentrated.

Since it is difficult to place the keep-alive electrode very close to the cone without touching it, a keep-alive to

cone distance of about 0.7 mm was finally chosen for further experimentation. The keep-alive depth of this tube was kept at zero. A fairly large keep-alive to cone distance is also necessary in considering the life of the tube.

### Gas Fillings

Nitrogen was chosen as the gas filling and it was admitted to the tube from an AIRCO nitrogen bottle and passed through a freezing-mixture trap maintained at about  $-70^{\circ}\text{C}$ . The attenuation obtained with nitrogen at various pressures is shown in Fig. 5. It is seen that the attenuation increases with the keep-alive current, and also increases when the gas pressure is

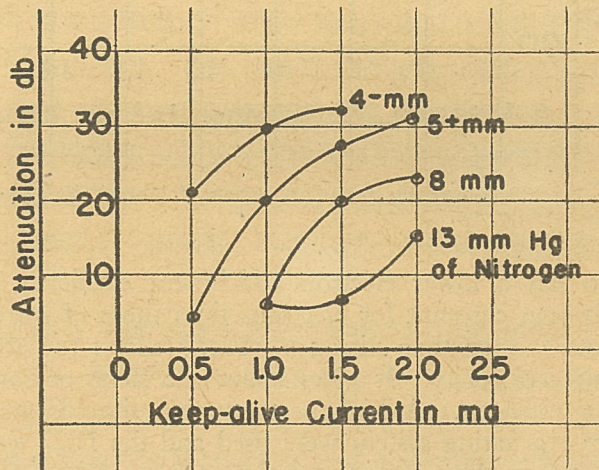


Fig. 5. Attenuation with nitrogen at various pressures.

reduced, similar to the case of a modified 1B24 as a 3 cm-band switch previously reported.<sup>1</sup> When the gas pressure is low, the gap voltage for the same keep-alive current increases when the pressure is reduced. The pressure versus gap-voltage curves for three keep-alive currents are shown in Fig. 6.

When used as a low level switch, the attenuation required is at least 25 db when the keep-alive is on. From Fig. 5, it is seen that when 4 mm Hg of nitrogen is used as a gas filling, a keep-alive current of about 0.7 ma is required to yield an attenuation of 25 db. The gap voltage is then from Fig. 6, about 400 volts. Thus, the power required is about  $\frac{1}{4}$  watt. It can be seen that about  $\frac{1}{2}$  watt is required for an attenuation of 30 db.

The life of such a tube filled with 4 mm Hg of nitrogen has been found to be very long as there was no appreciable change of the tube characteristics after operating for several hundred hours at a keep-alive current of 1 ma. This is understandable because a distance of 0.7 mm is not easily bridged

over by the conductive dirt produced by cathode sputtering or chemical deposits.

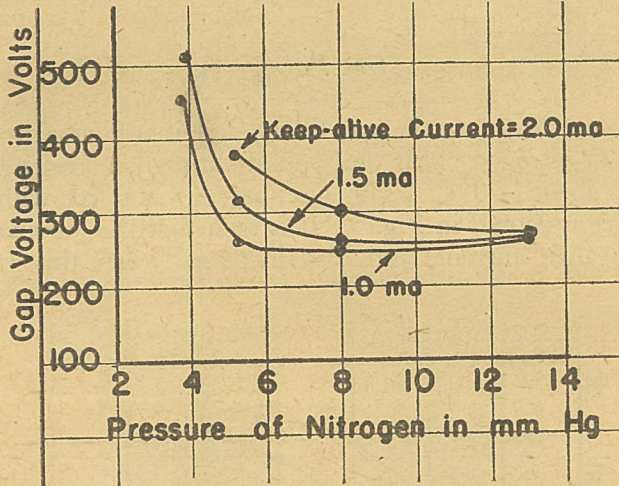


Fig. 6. Gap voltage versus gas pressure (nitrogen) for various keep-alive currents.

Since argon has a lower electron attachment coefficient and a higher differential ionization constant for electrons than those of nitrogen, it might yield a higher attenuation than nitrogen. Fig. 7 shows the attenuation with argon of commercial purity. It gives about the same or somewhat larger attenuation than nitrogen. A higher attenuation should be obtained with argon if a better evacuating system were used and the 1B27 were thoroughly baked out before the admission of argon.

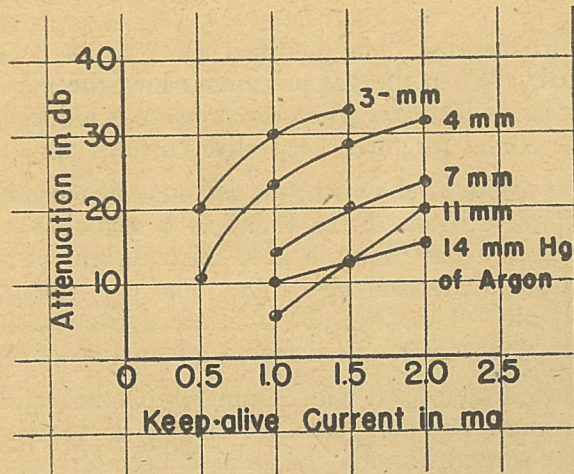


Fig. 7. Attenuation with argon at various pressures.